Chapter 4

Characterizing the Nature and Extent of Contamination

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4.0 Introduction

If screening does not reveal contamination at concentrations that exceed land use-specific criteria, the screened area may be eligible for closure without further investigation. However, if screening or historical information indicates that further site investigation is warranted, it is appropriate to proceed with the characterization of the nature and extent of contamination.

Nature and extent characterization must address all affected media (certain program limitations apply - see RISC User's Guide) but the purpose of characterizing each of the media is different. Surface soil is characterized to evaluate direct contact, whereas subsurface soil characterization focuses primarily on the potential for COCs to leach to ground water. Ground water contamination is characterized (1) to determine if the ground water has been or potentially could be degraded and (2) to evaluate potential routes for human exposure.

In all cases, the potential for ecological impacts must also be evaluated. A thorough nature and extent characterization defines the size of the source area, provides data to determine the potential exposure concentration (PEC), and establishes source area boundaries for remedial activities. The nature and extent characterization process should be consistent with remediation and closure objectives for the site.

4.1 Applicability and Scope

For soils, the "nature" of contamination is defined as those site related chemicals of concern and their respective concentrations. The "extent" is defined as the vertical and horizontal distribution of chemicals of concern whose concentrations exceed residential closure levels. For large sites with multiple source areas, it may be appropriate to delineate to commercial/industrial closure levels on each individual source area, and demonstrate residential levels are not exceeded at the property line. The vertical extent is defined as the distribution of contaminant concentrations that exceed the land use specific closure level.

If COC concentrations for surface and subsurface soils are less than the closure levels, a nature and extent determination is generally not required. However, if COCs are detected in ground water at *any* level during screening, the nature and extent of ground water contamination must be characterized. Because ground water is mobile, it is not possible to determine whether any individual sample is located in an area of higher concentration or lower concentration within the ground water plume.

An evaluation of the nature and extent of contamination should include the following tasks:

- Identify affected media (surface soil, subsurface soil, ground water, surface water, sediments, and air)
- Identify COCs
- Delineate the vertical and horizontal extent of contamination in each medium
- Determine potential human and ecological receptors and exposure pathways
- Provide sufficient information to make preliminary decisions on remedies and default or nondefault closure options available for the source area

Characterizing the nature and extent of contamination involves three basic steps (see Figure 4-1):

- Planning

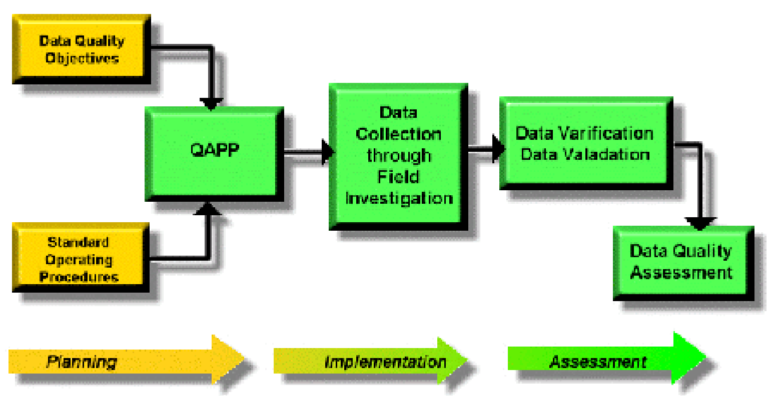

Figure 4-1. Site Characterization Process

  – Develop a strategy to characterize the nature and extent of contamination

- Update the Quality Assurance Project Plan (QAPP)

- Implementation
  - Conduct field investigations

- Assessment
  - Validate and assess data to determine how to proceed

These steps present a logical approach to use during every round of sampling. Although the approach (planning, implementation, and assessment) is basically the same for both nature and extent and closure sampling, the specific requirements for collecting samples differ. This chapter discusses the specific requirements for characterizing the nature and extent of contamination; Chapter 6 discusses closure sampling.

Planning

Developing a site characterization strategy continues the process of compiling and reviewing information gained during presampling and area screening. Such information should be used to update the conceptual site model (CSM) to include any identified source areas and contaminated ground water. The updated CSM can be used to help identify data gaps and to establish initial objectives for continuing the nature and extent evaluation.

The next iterative step in the process involves developing a QAPP. If a QAPP was developed for the area screening evaluation, it should be revised or expanded to address the requirements for characterizing the nature and extent of contamination. Section 3.2 provides more details regarding the required QAPPs.

When applicable, the following issues should also be considered:

- When determining partitioning coefficients for metals and a limited group of ionizing compounds, soil pH in the source area should be considered. These constituents include but are not limited to arsenic; cadmium; chromium; 2-chlorophenol; 2,4-dichlorphenol; and others (see Appendix 1). This simple measurement may be made in the field with a pH meter in a soil/water slurry (McLean 1982).

- For areas where bedrock occurs less than 10 feet from the COC source area, the default soil to ground water partitioning model may not be applicable.

- Permission may be needed to investigate an adjacent property. IDEM may, at its discretion, assist in gaining property access. IDEM may also assist in determining appropriate alternative actions.

Implementation

The next step in characterizing the nature and extent of contamination involves the field investigation. Data from samples collected in accordance with the QAPP can be used to define the vertical and horizontal extent of contamination in the affected media. In addition, the user should gather any other site data, such as soil pH, applicability of the default ground water partitioning model, and property access necessary to establish potential remedies or models for the risk assessments.

Assessment

Data validation and useability reviews are the final steps in characterizing the nature and extent of contamination. The CSM should be updated as needed based on field investigation data. Data gaps should be identified, and the QAPP should be revised to address the gaps. For instance, surface soil COC concentrations may be higher than expected, or the lateral extent of contamination may be greater than expected. These differences may require that preliminary remedies be reconsidered.

The site characterization process outlined above should be repeated in an iterative fashion until all source areas and ground water plumes are fully characterized. When characterization is complete, the model should be finalized. At that point, an informed decision can be made regarding remedy and closure options (default or nondefault) for the site.

Sections 4.2 through 4.5 provide additional details and specific guidance on how this process is applied to characterize site contamination.

4.2 Planning: Developing a Strategy to Characterize the Nature and Extent of Contamination

When developing a site characterization strategy, it is necessary to understand and make use of all the site information, observations, and data collected to date. The appropriate tool for organizing this information is the CSM, which provides a complete "picture" of site contamination (see Section 2.10). Understanding the type of contamination present and its potential risks to human health and ecological receptors are the most important aspects of developing the model.

A holistic approach to a site or source area within a site may be appropriate for COC characterization and closure. An example of a holistic approach is establishing a single boundary of compliance to evaluate a number of potentially contaminated areas at a site. If applicable, this approach (rather than an individual source area approach), may reduce costs and increase efficiency while still protecting the environment.

The remainder of Section 4.2 provides more details on updating the CSM, considering potential remedies and nondefault options, and identifying data gaps.

4.2.1 Update and Expand the CSM

If area screening data was collected, the preliminary CSM developed during presampling should be updated and expanded before additional field activities are conducted. The updated model should include a top view site plan, cross-sectional drawings depicting site geology and hydrology, and any data on subsurface COC concentrations. The RISC portion of the IDEM website (www.state.in.us/dem/olq/risc) includes risk assessment software that contains information for developing a CSM. The model should include updated information on each of the five categories below, as applicable:

1. **General site information** such as location, size of property, source location, ownership, years of operation, contractors, and other relevant background information

2. **Site characteristics** such as hydrogeological features, hydraulic conductivity, gradient, aquifer thickness, infiltration rate, characteristics of surrounding sites, water use, meteorological conditions, fraction of vegetative cover, and other relevant features

3. **Exposure pathways and receptors** such as current site use, surrounding land uses, projected future land use, exposure areas, source of releases, affected media, plant consumption, affected populations, sensitive subpopulations, ecological concerns, or other pathway and receptor information

4. **Contamination source characteristics** such as spills, drum storage activities, solvents used, waste oil handling, history of contamination, any remedial actions, source depth, area, and presence of free product

5. **Concentrations and types of COCs**, including approximate concentrations detected during screening or previous sampling efforts

4.2.2 Consider Potential Remedies and Nondefault Options

The revised CSM can be used to consider potential remedies and default or nondefault options that may be appropriate for achieving closure based on available information. At this point, the data needed and the statistical methods and models that may be appropriate for the remedies and closure options should be considered.

In many cases, samples required for the various remedies and risk assessments may be collected during sampling efforts to determine the horizontal and vertical extent of contamination. This approach may save time and money.

For example, if a site-specific soil saturation limit is going to be calculated as part of a nondefault risk assessment, samples from each soil boring may be collected using an appropriate methodology, such as split-spoon sampling (see Chapter 7). One sample could be analyzed for COC concentrations and the other analyzed for relevant soil characteristics. In this example, the following site-specific soil information would be required: dry soil bulk density, fraction of organic carbon, water-filled soil porosity, and air-filled soil porosity. This information should be representative of the whole source area and must be analyzed by a soil laboratory using accepted and appropriate methods. Alternatively, if a nondefault risk assessment using a fate and transport model is desired, additional hydrogeological data may be needed (see Chapter 7).

4.2.3 Identify Data Gaps

As noted above, completely characterizing a source area requires determining the vertical and horizontal extent of all COCs in all media, including surface water, sediments, or air. Compiling a list of needed data should identify the probable locations and number of samples to be taken in each of the affected media. Careful assessment of data gaps may save time and money.

In some cases, data needs will be quite simple; in other cases, the required investigation may be quite complex. For example, if a highly mobile COC reached ground water and could potentially affect surface water, the investigation may require an evaluation of regional water uses, land uses, ecological impacts, potential migration to sediments or surface water, recreational exposures, and possible air emissions. These potential effects require additional data collection for all media and receptors that may be affected. Conversely, if a leaking underground storage tank were removed, and the area screening evaluation indicated that contamination was limited to the subsurface soil immediately surrounding the tank, with no ground water impact, then the investigation of the nature and extent of contamination would not need to consider the effects of the release on regional water wells or aquatic species near to the site.

Whatever degree of complexity is required for an investigation, the CSM should provide the information needed to determine the most appropriate type of investigation. The model should also show how the contamination may be linked to various exposure pathways and receptors.

4.3 Planning: Revising a QAPP

The next step in the site characterization process involves modifying elements of the QAPP to gather the data needed to support the required investigation.

As described in Section 3.2, a QAPP should be revised to include a detailed description of where and how samples are collected, the type and number of samples, and an assessment of results. The QAPP should contain the following elements:

- Data Quality Objectives (DQOs)
- Health and Safety Plan (HASP)

- Sampling and Analysis Plan (SAP), including Quality Assurance/Quality Control (QA/QC)

- Data Quality Assessment (DQA)

If a QAPP was established for area screening, it can be modified or expanded to address any additional data collection elements.

Data Quality Objectives

The initial characterization of source areas often raises as many questions as it answers. Field screening methods (such as the use of colorimetric field kits, photoionization detectors, and flame ionization detectors) may require that the sampling plan be redirected or the proposed remedies be reevaluated.

A general description of DQOs and the process used to develop them is included in Section 3.2.1. The DQO process for determining the vertical and horizontal extent of contamination is fairly straightforward.

The first step of the process is to state the problem in terms of the nature and extent of contamination at the site. COCs, their concentrations, and the matrix of each COC should be determined. The next step is to determine the amount of sampling needed. As a general rule, if no constituent is detected at concentrations exceeding the levels defined in 4-1, sampling is complete because the horizontal and vertical extent of contamination has been determined.

The next step involves specifying limits on decision errors. To limit decision errors, specific analytical methods and sample protocols are required. An array of analytical protocols that meet quantification criteria is provided in Appendix 2.

Additional DQOs may be required for other types of sampling performed to completely characterize the site, such as gathering data on soil characteristics for a risk assessment. The DQO process will need to be applied individually to each media and COC being considered. This approach will result in working through the elements in the process several times for each area of contamination. The QAPP should incorporate the sampling needed to support all of the DQOs. This approach will help indicate where data needs overlap and where the same data or samples can be used for a variety of objectives, minimizing sampling and analysis costs.

Health and Safety Plan

Guidance on the health and safety portion of the QAPP appears in Section 3.2.2. If the HASP was prepared in support of an area screening evaluation, it should be reviewed and updated to address any additional sampling and field activities to be performed. In all cases, the HASP must comply with the requirements of 29 CFR 1910.120.

Sampling and Analysis Plan

After DQOs are established, a SAP should be developed. The SAP should identify where samples will be taken and how they will be collected and analyzed. Implementation of the SAP should follow the requirements of the field investigation for each media and for background sampling (see Section 4.4).

A key element of the SAP is the description of QA/QC requirements. Section 3.2.4 provides minimum QA/QC requirements for various IDEM programs. A general discussion of the contents of the SAP also appears in Section 3.2.3.

Data Quality Assessment

The discussion of DQA provided in Section 3.2.5 also applies to the characterization of the nature and extent of contamination. DQA should be appropriate for the DQOs established to determine the nature and extent of contamination.

4.4 Implementation: Field Investigations

The goal of sampling activities identified in the sample design is to provide data to support decisions that meet DQOs. The following are examples of some common goals:

- Determine the vertical and horizontal extent and concentration of COCs
- Gather information to meet additional source area requirements
- Study the migration and transformation of COCs

Selecting sample locations to determine the nature and extent of contamination is a critical step in evaluating concentrations at a source area. Two basic sample methodologies are available for collecting environmental samples: *statistical* and *judgmental*. Several distinct site areas may have different COC concentrations or characteristics. For this reason, horizontal stratification of the site is necessary, and each area should be evaluated individually.

Statistical sampling is usually the best method when little information is available about an area or stratum. Most contamination in soils tends to be highly variable in its distribution. Therefore, if simple random sampling (SRS) is used to identify contamination in a large area, a large number of samples may be required to ensure that contaminated areas are found and characterized accurately. See Chapter 1, page 1-14 for a discussion of using the coefficient of variation to evaluate samples. Details of statistical sampling methodologies and sample placement options can be found starting on page 102 of the EPA *Soil Screening Guidance: Technical Background Document* (1996).

Judgmental sampling may be appropriate when a great deal of information is available regarding site contamination. Judgmental sampling selects sample locations based on knowledge of the site and the physical or chemical characteristics of the known COCs. Determining locations for horizontal sampling of soil and ground water is based in part on an evaluation of the site history. Using judgmental sampling to investigate a site relies on any current and past information sources that may provide site-related data on current and historical operations.

4.4.1 Field Investigation of the Nature and Extent of Soil Contamination

Evaluating the nature and extent of contamination will provide potential exposure concentrations (PECs) that can be compared with closure levels to determine the need for remedial action.

The surface soil sampling strategy should be designed to collect data that will be useful for evaluating PECs for direct contact (direct ingestion, dermal absorption, and inhalation of fugitive dust). Historical information (see Section 2.2) and the revised CSM (see Section 4.2) may be useful in identifying specific locations for evaluation. Sampling results from the Chen test may provide specific locations to sample if COC concentrations in tested areas exceed default closure values.

To determine the horizontal extent of soil contamination, IDEM recommends that samples be collected from at least 14 borings in each 0.5-acre source area. The 14 borings should include 10 source area borings that define the PECs. The other four borings should be located along each of the four general geographic directions (upgradient, downgradient, and the two side gradients) to define COC boundaries. The analyses from these four sampled borings are not used in the PEC evaluation. For smaller source areas, the minimum recommended number of borings is indicated in Table 4-1.

Table 4-1. Minimum Number of Soil Borings to Calculate a PEC

Source Area (Acres)	Number of Borings for Concentration Gradient	Number of Borings for Geographic Characterization	Total Number of Definitive Borings
1/10	3	4	7
¼	5	4	9
½	10	4	14

To determine the vertical extent of contamination in subsurface soil, refer to Section 3.4.3. To determine the vertical extent of contamination, samples may be collected from the same borings identified in Table 4-1.

4.4.2 Field Investigation of the Nature and Extent of Ground Water Contamination

An investigation of ground water contamination includes determining the extent of contamination and the perimeter of compliance (POC). The requirements for each determination are presented below.

4.4.2.1 Determining the Extent of Ground Water Contamination

Ground water contamination is always be evaluated horizontally to the point where concentrations in affected media are less than residential default closure levels. IDEM recommends first defining the horizontal extent of contamination outward from the source using intrusive (push-probe) methods. To define the vertical extent of contamination, exploratory borings may be converted into monitoring wells with depth-specific screened intervals. Information from the initial investigation can be used to plan the location and installation of monitoring wells or piezometers to determine hydraulic characteristics and the extent of contamination. Monitoring wells may be required for confirmation and closure sampling. The Indiana Department of Natural Resources' rule 312 IAC 13 is a good source of information on the construction of ground water monitoring wells.

A minimum of three wells or piezometers is needed to determine the local horizontal hydraulic gradient and flow direction of an aquifer. IDEM recommends a minimum of one well upgradient of a COC source. The upgradient well should be located so that it is not influenced by the source when conditions change due to seasonal variability or other factors.

Information on additional aquifer characteristics, such as vertical hydraulic gradient and vertical extent of contamination, may also be needed. The need for this information depends on COC types, program requirements, and factors that may influence flow, such as well fields or a leaky aquifer.

Monitoring wells may be placed downgradient of a source for multiple purposes, including determining the extent of a contaminant plume, POC, or changes in flow direction. Permanent closure of a site with a ground water contaminant plume requires that wells be located in the interior of the plume (see Appendix 3 for guidance).

Pump or slug testing may be necessary to determine hydrogeologic conditions such as conductivity, storativity, and transmissivity of the source area. The following questions must be answered to adequately characterize ground water impacts:

- Are the aquifers and transmissive zones in the area reasonably mapped?
- Is there concern about leaky aquifer conditions (that is, can water and COCs move from one aquifer to another)?
- Is there a vertical hydraulic gradient or perched ground water?

4.4.2.2 Determining the Perimeter of Compliance

IDEM's ground water policy requires "no further degradation" of ground water, which means that the plume is either stable or shrinking with respect to chemical concentration and spatial extent. Samples taken outside the boundary of such a plume must meet the default land use closure levels for each COC.

Location of POC

When there is human or ecological exposure within the contaminant plume area, the POC is established as the location where exposure occurs. When there is neither human nor ecological exposure within the contaminant plume area, the POC is defined as the perimeter that is representative of the point at which ground water COC concentrations are equal to or less than land use-specific closure levels (see Figure 4-2).

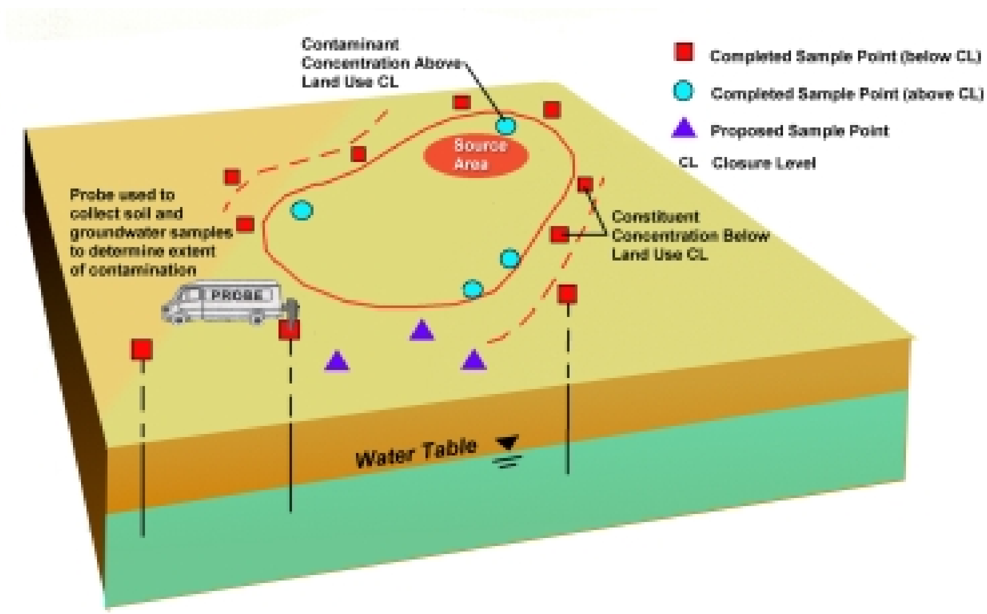

Figure 4-2. Establishing the Perimeter of Compliance

Additional POC Requirements

Establishing the POC is contingent on the following conditions:

- There is no human exposure to ground water COCs (constituents at concentrations that exceed residential default closure levels).

- At the time of initial discovery of chemical constituents in the ground water, a well managed investigation should be conducted to ensure that there is no further degradation of the ground water from constituents associated with source areas inside the POC. POC wells will be placed in appropriate locations at the conclusion of a thorough and timely investigation of the ground water.

- The site poses no threat from flammable vapors.
- All free product is recovered to the extent practicable.
- The established POC is not in conflict with susceptible area requirements.
- IDEM may require full COC cleanup, even at the source, if necessary to protect human health and the environment.
- All present and future land uses must be considered and addressed by (1) providing verification that no change in future water supply use is anticipated within the POC and (2) providing an institutional control to restrict exposure to COCs.
- All COC isopleth maps clearly depict the POC.
- POC wells will be utilized, as appropriate, as sampling points for plume stability demonstrations (see Appendix 3).
- Multi-constituent plumes present special challenges. Often an indicator constituent can be selected to guide the location of the POC. This indicator constituent should be selected in consultation with IDEM staff, and should be based on chemical behavior and constituent concentration data. IDEM generally does not require multiple POCs for a multi-constituent plume.

Under certain conditions, IDEM may approve requests to maintain an off-site POC

POC with Property Control

"Control" of all property affected by the ground water plume must be demonstrated. Property control is defined as the demonstrable capacity to monitor and restrict access to the affected media through institutional or engineering controls. Evidence of control is typically documented in the form of an institutional control recorded on the deed of the affected property (see Figure 4-3).

POC without Property Control

If a plume extends into an area that is not controlled by the site owner or operator or if it extends into an area for which access has not been granted, the POC will be placed at the site property line (or at the point property control ends). Contamination outside of the POC must be remediated to residential closure levels. In such cases, a POC remedial plan must be designed and implemented (see Figure 4-4).

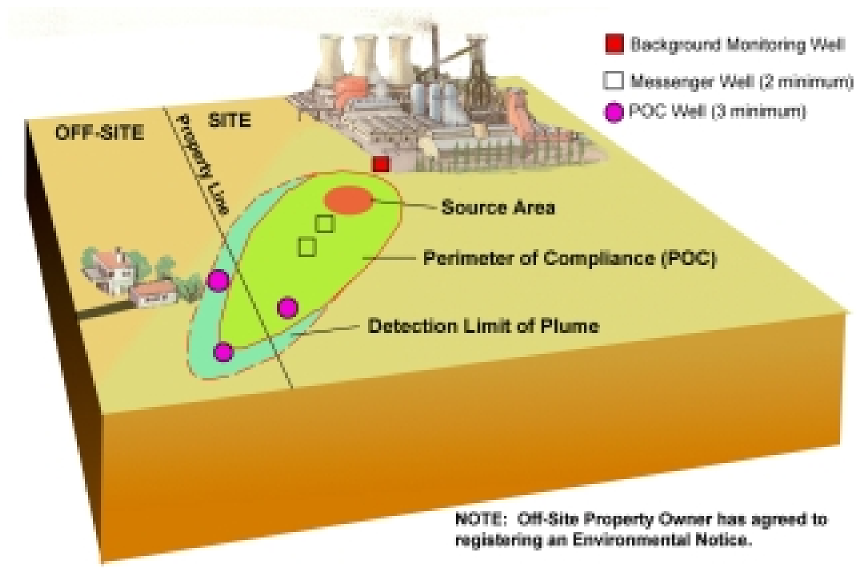

Figure 4-3. Off-Site POC with Property Control

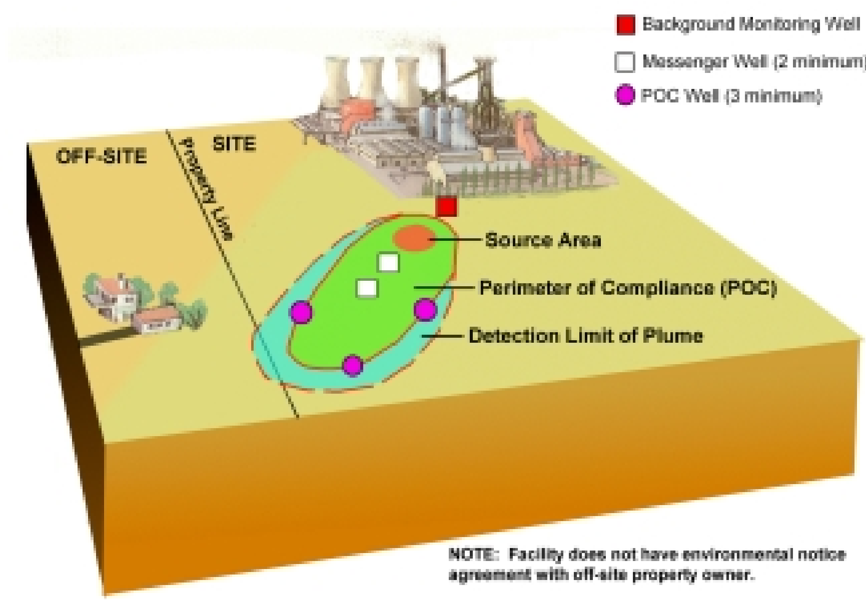

Figure 4-4. POC without Property Control

POC Remedial Plan

It may be necessary to develop and implement a remedial plan if COC concentrations increase significantly at the POC during quarterly sampling events. The remedial plan should include an implementation and compliance schedule. The goal of the remedial plan is to stabilize the plume at the POC and demonstrate that the plume will stabilize or decrease in concentration when remediation is complete. The POC remedial plan must be submitted to the appropriate IDEM program within 60 days of determining that contamination exceeds closure levels at the POC. The plan should address applicable programmatic remedial options, which may include COC source reductions, hydraulic control of a plume, or a nondefault assessment to model and monitor future stability and compliance with the POC.

4.4.3 Field Investigation of the Nature and Extent of Contamination in Other Media

The nature and extent of contamination in other media may need to be determined. Determining the nature and extent of contamination in surface water, sediments, and air is discussed below.

4.4.3.1 Surface Water

Evidence of drainage or discharge to surface water near a source area should be reviewed carefully. Surface waters include but are not limited to rivers, streams, creeks, reservoirs, lakes, ponds, wetlands, and free-flowing underground streams. Under RISC, surface water is considered an ecologically susceptible area. Evidence of impacts to surface water will require a nondefault risk assessment to evaluate impacts to biota. Surface water closure levels are not included in this version of RISC.

4.4.3.2 Sediments

A common problem associated with surface water contamination is sediment contamination and its associated affect on aquatic organisms particularly in their larval or juvenile life stages. Sediments may be a major repository for some of the more persistent constituents released into the overlying surface waters. Sediments primarily consist of particulate matter, typically mixtures of clay, silt, sand, organic matter, and minerals. This matrix of materials can be relatively heterogeneous in terms of physical, chemical, and biological characteristics.

Many factors determine the relative partitioning or sorption of a compound between water and sediment. A few of these factors include the compound's aqueous solubility, pH, affinity for sediment organic carbon and dissolved organic carbon, and oxidation-reduction potential, as well as the grain size of the sediment. Evidence of COC migration from surface waters to sediment should be reviewed carefully. Evidence of impacts to sediment will require a nondefault risk assessment. Sediment closure levels are not included in this version of RISC. A possible sediment closure level may be identified using the RCRA QAPP, Instructions, EPA Region 5, April 1998, Appendix C.

4.4.3.3 Air

Ambient and indoor air contamination is another area that is not specifically addressed under default RISC closure levels. In the default exposure equations, RISC considers volatilization and inhalation from soils and inhalation from indoor exposure to ground water. However, issues such as excessive fugitive dust and ambient and indoor air concentrations are not considered. Where applicable, care should be taken to characterize these potential pathways (such as volatilization from surface impoundments, excessive wind blown dust, and vapor intrusions). Any suspected air emissions must be characterized. Evidence of air contamination will require a nondefault risk assessment. Air closure levels are not included in this version of RISC.

4.5 Assessment: Data Validation and Usability

After field investigation data is collected, it should be evaluated for its conformity with DQOs. If data conform to DQOs, the data should be incorporated into the CSM. When the horizontal and vertical extent of contamination is fully depicted in the CSM, the need for any additional sampling should be clear.

Based on this information, potential remedies and additional analyses appropriate for the area should be considered, as well as if any additional sampling is necessary. The fate of each COC should be considered carefully, and the COC should either be addressed or eliminated from further consideration. The evaluation of exposure pathways and transport mechanisms should also be reviewed carefully, and temporal trends should be analyzed. By reviewing and considering all relevant information, a more informed decision can be made regarding how to proceed with closure.